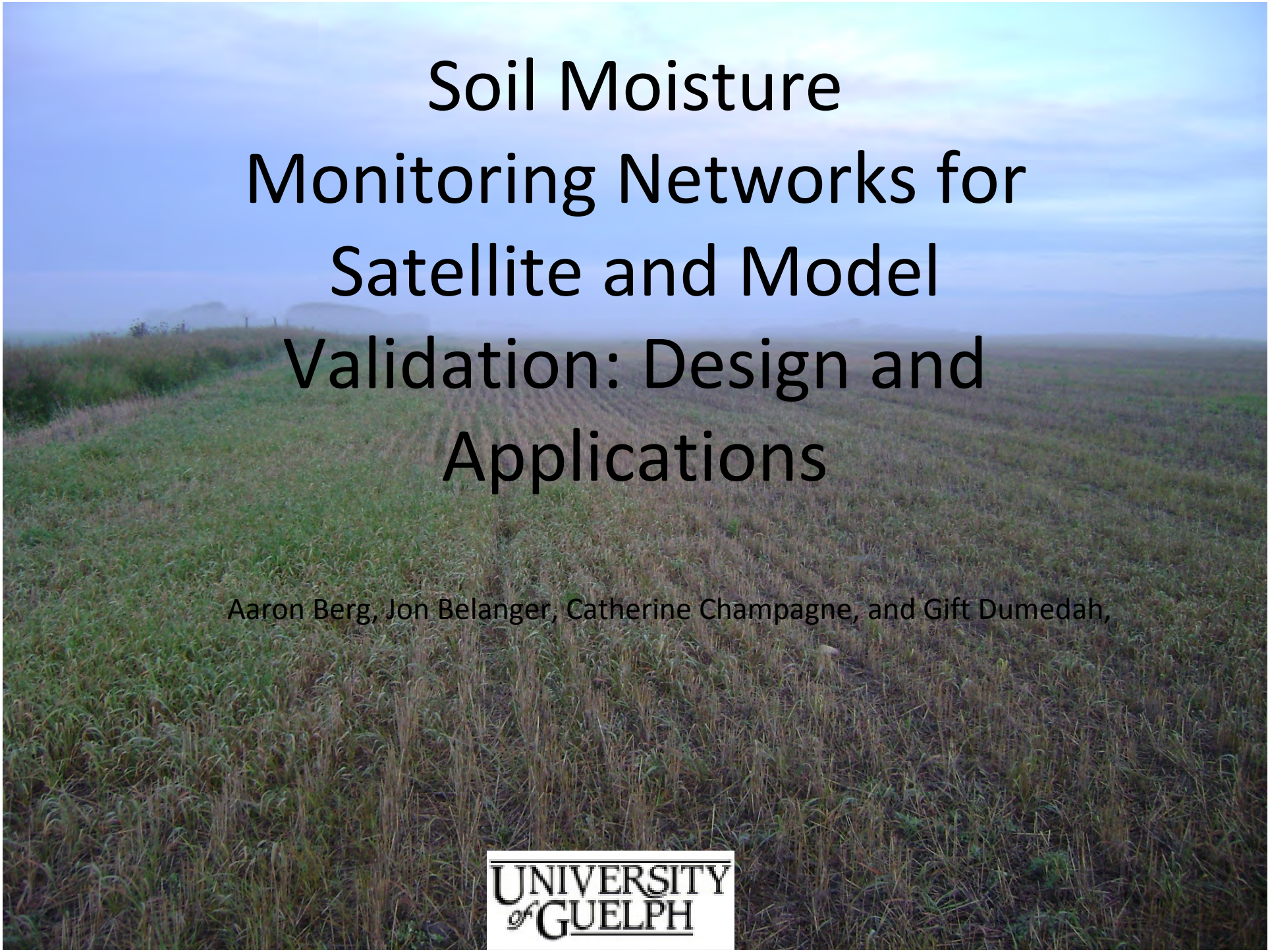
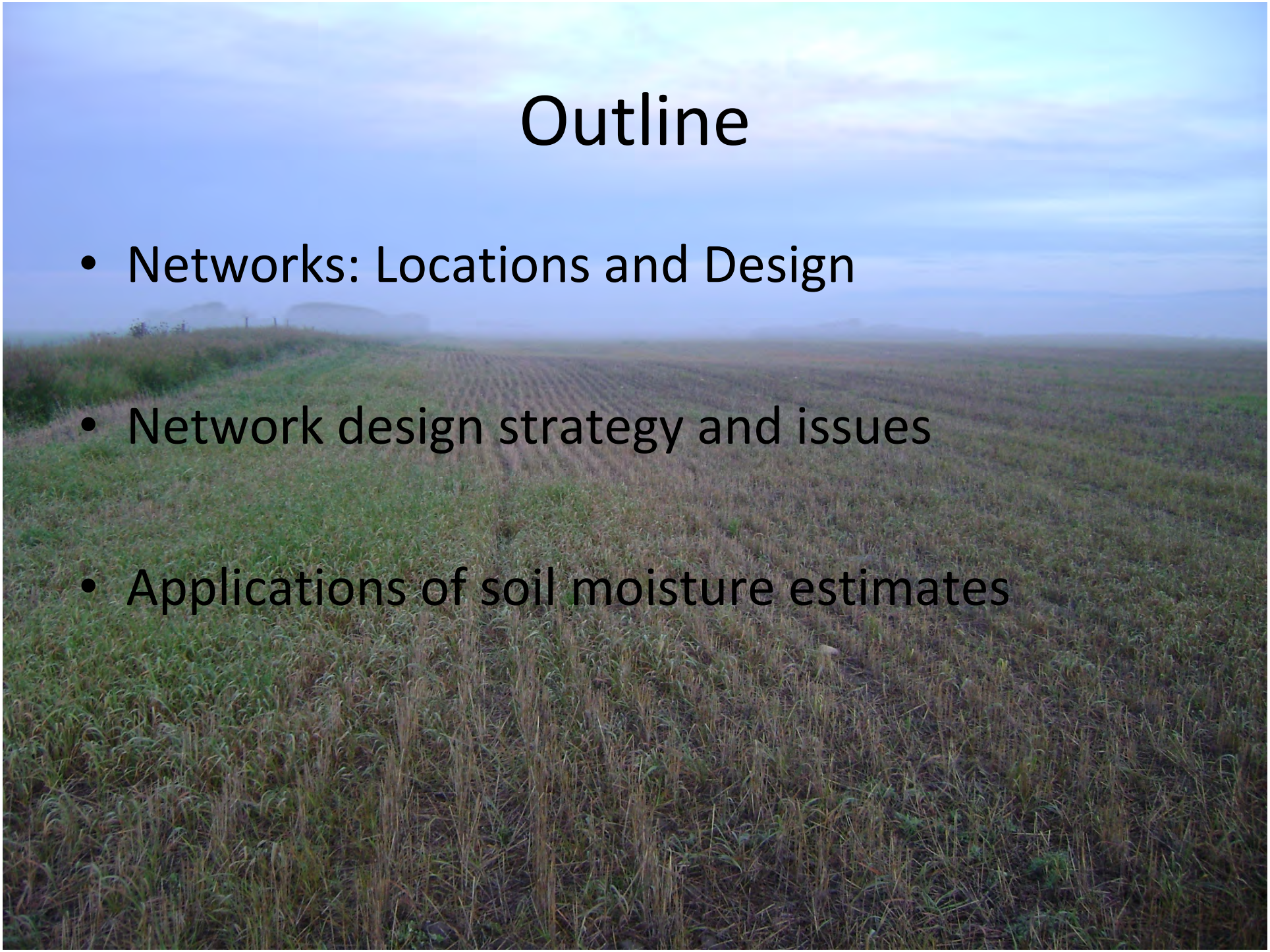


Soil Moisture Monitoring Networks for Satellite and Model Validation: Design and Applications

Aaron Berg, Jon Belanger, Catherine Champagne, and Gift Dumedah,

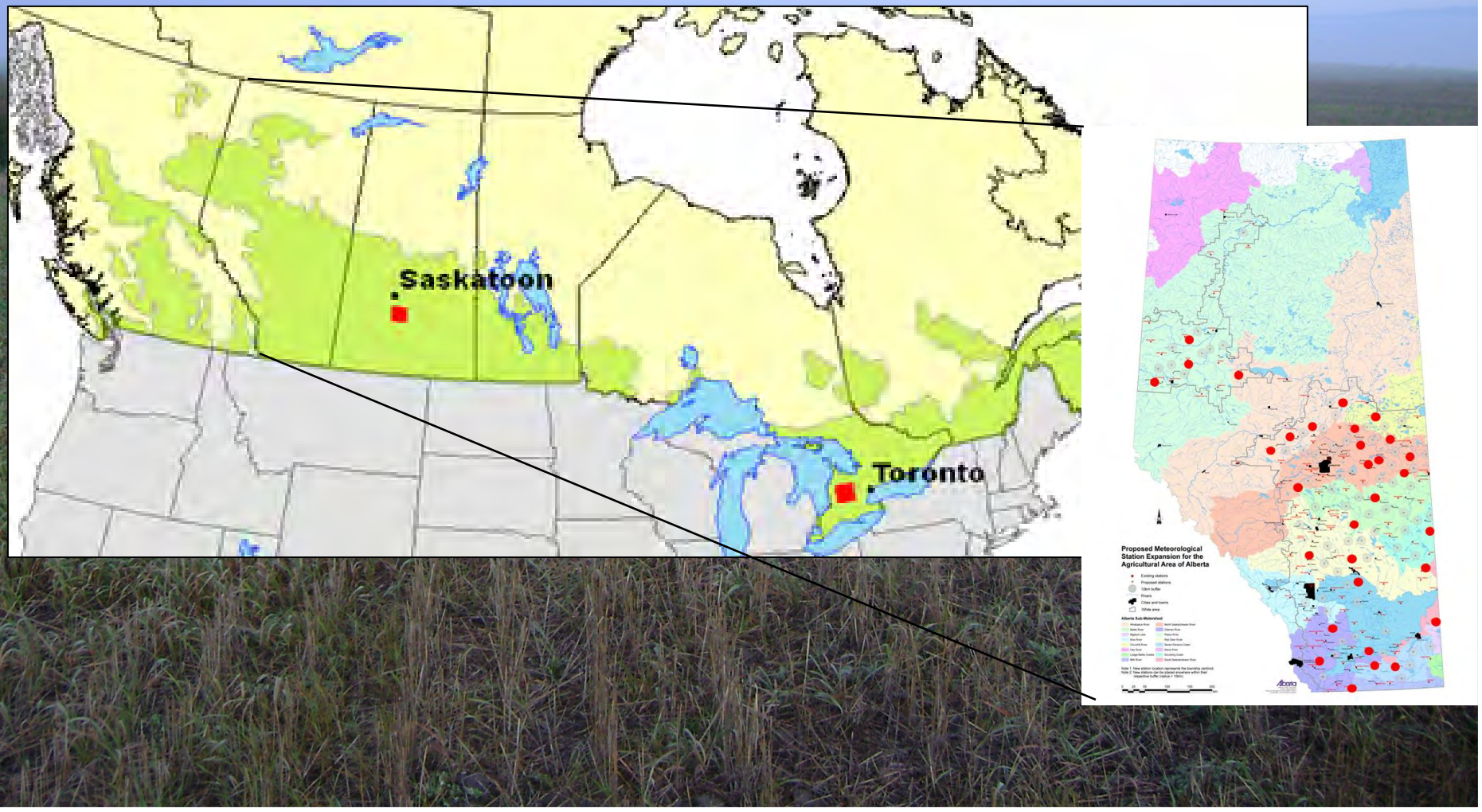
UNIVERSITY of GUELPH



Outline

- Networks: Locations and Design
- Network design strategy and issues
- Applications of soil moisture estimates

Soil Monitoring Moisture Networks in Canada

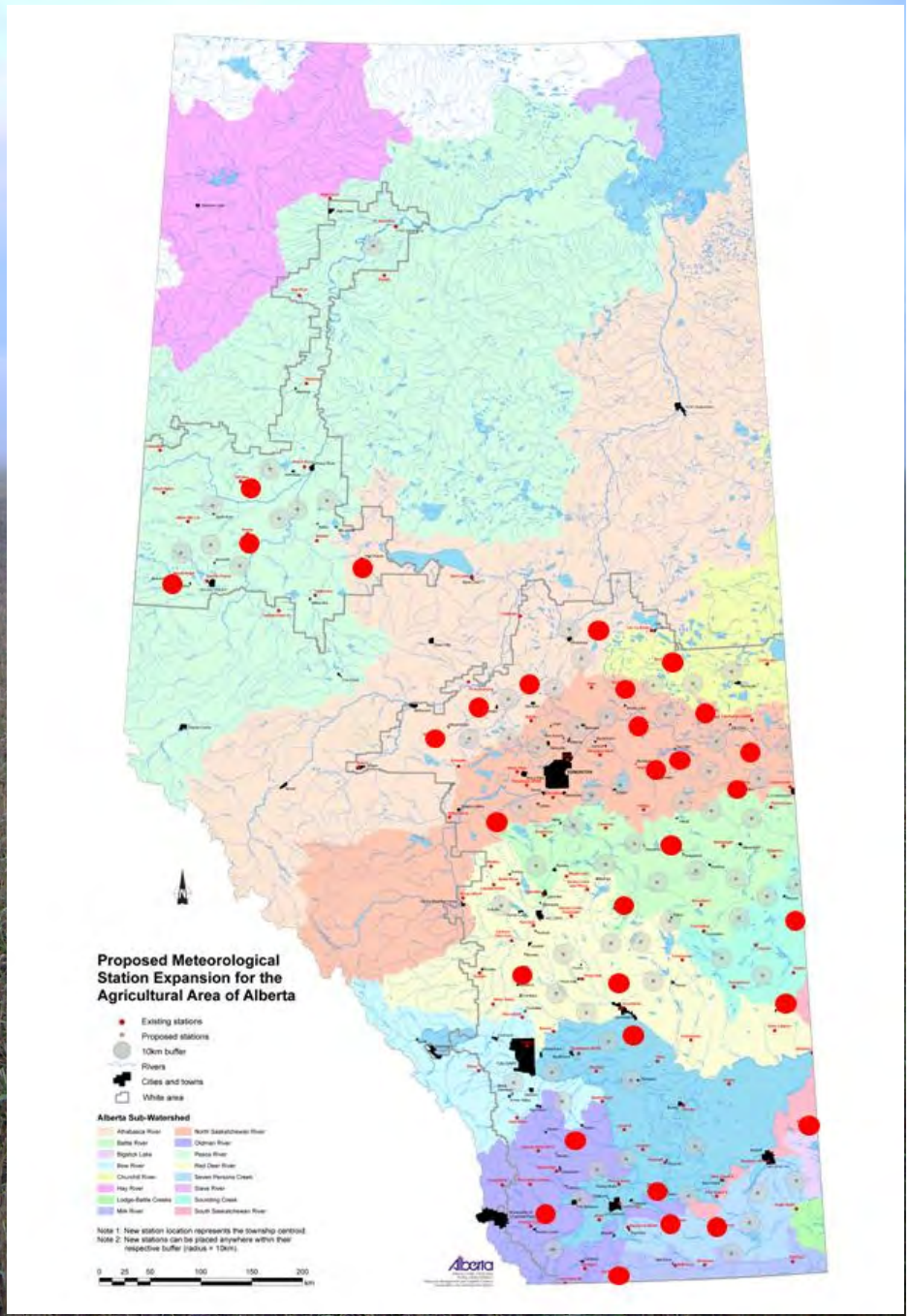


Alberta DroughtNet

Existing Network:

2003 – Present.

- Full meteorological station at each site
- Delta T Theta Probes
- Sampling at 5, 20, 50, and 100cm



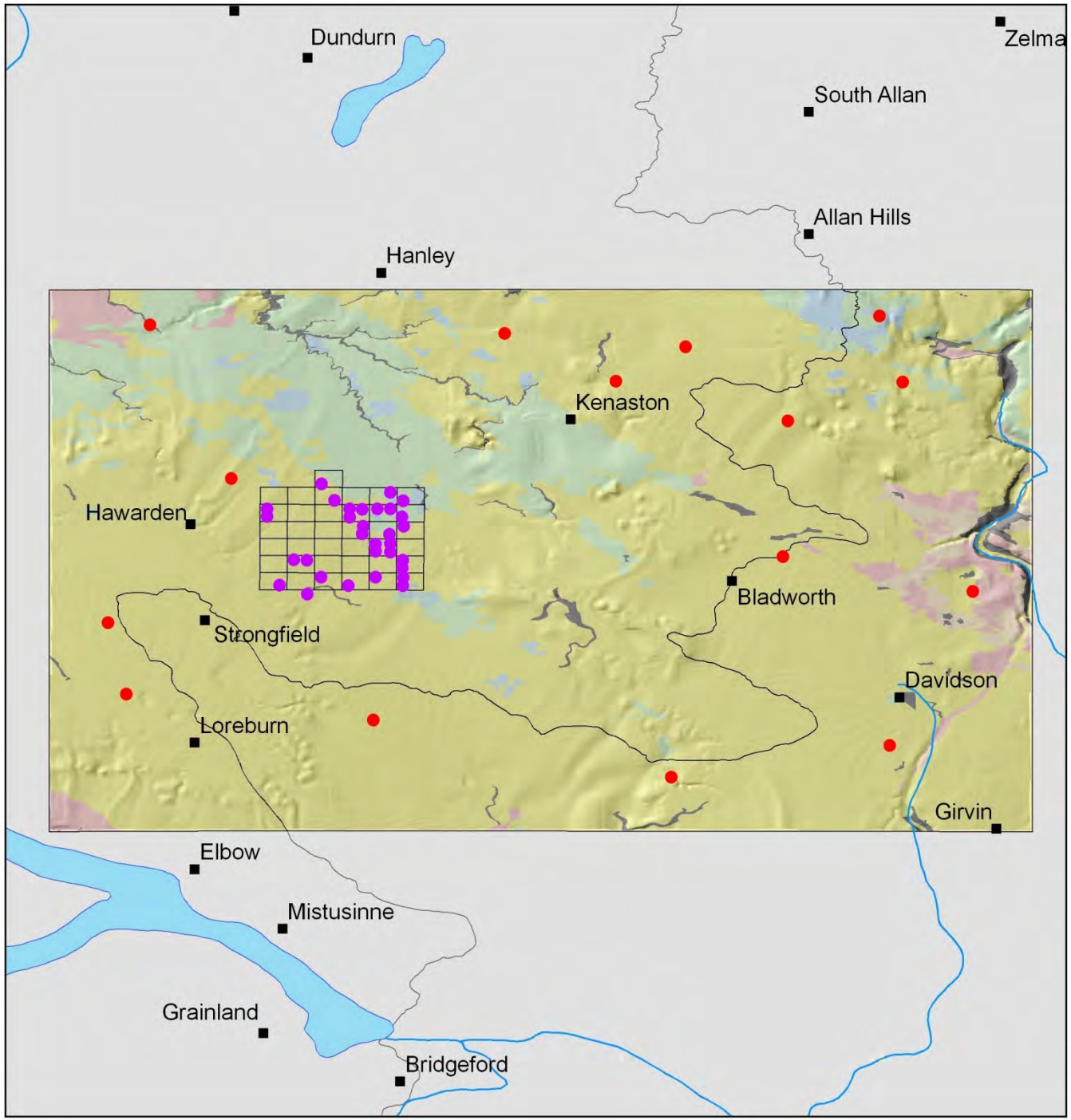
Walker, B.D. and A.E. Howard, 2003.

Ontario and Saskatchewan Paired Soil Moisture Networks

- Two soil moisture monitoring networks 60X60 km resolution
- Sampling at 5, 20 and 50cm depths

- Temporal Frequency :
  Hourly
- Variables Observed:
  Soil temperature
  Soil Moisture
  Precipitation

SOIL TEXTURES IN SASKATCHEWAN OBSERVATORY



N

1:500,000

0 2.5 5 10 15 20 25 Kilometers

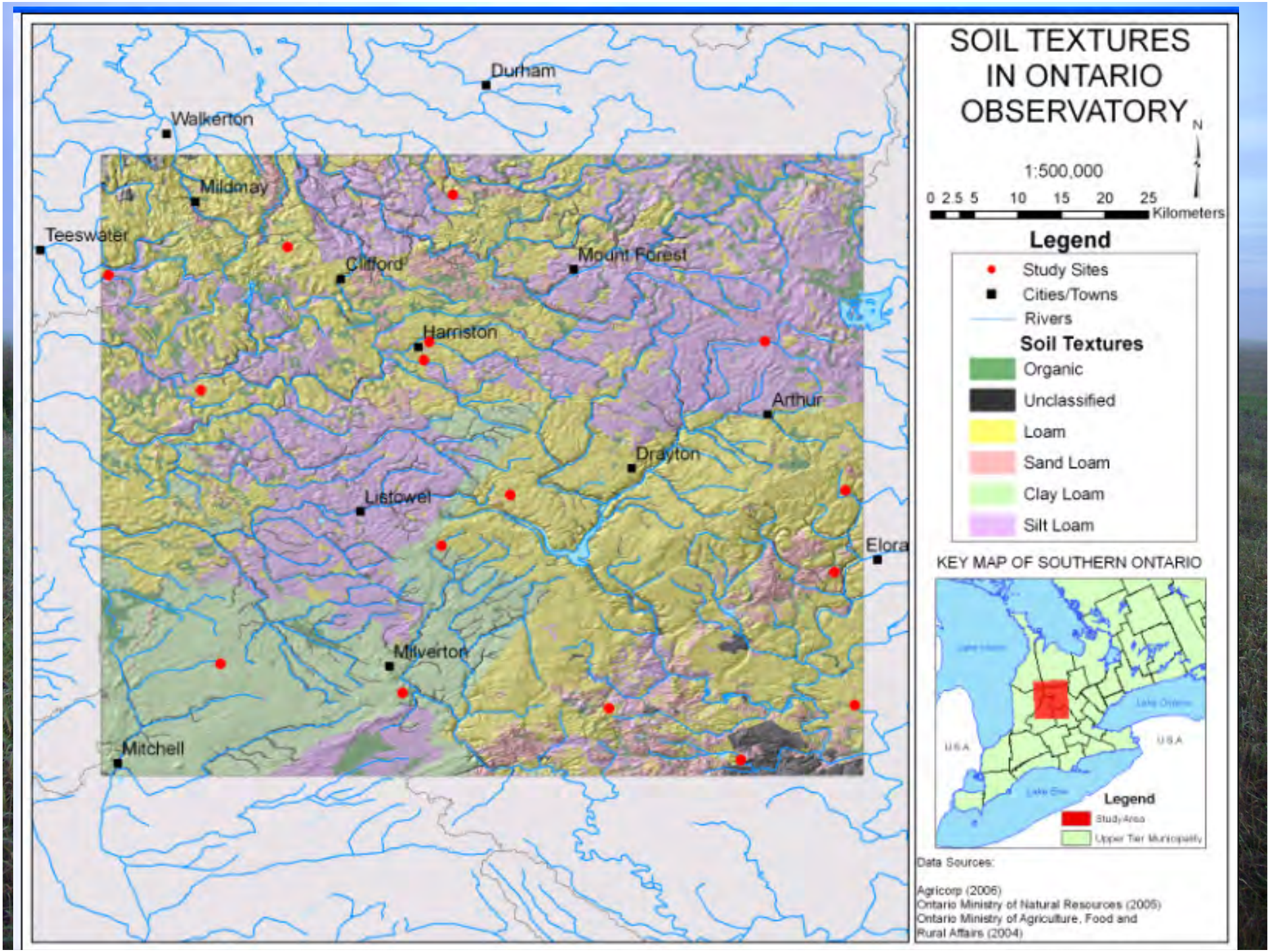
Legend

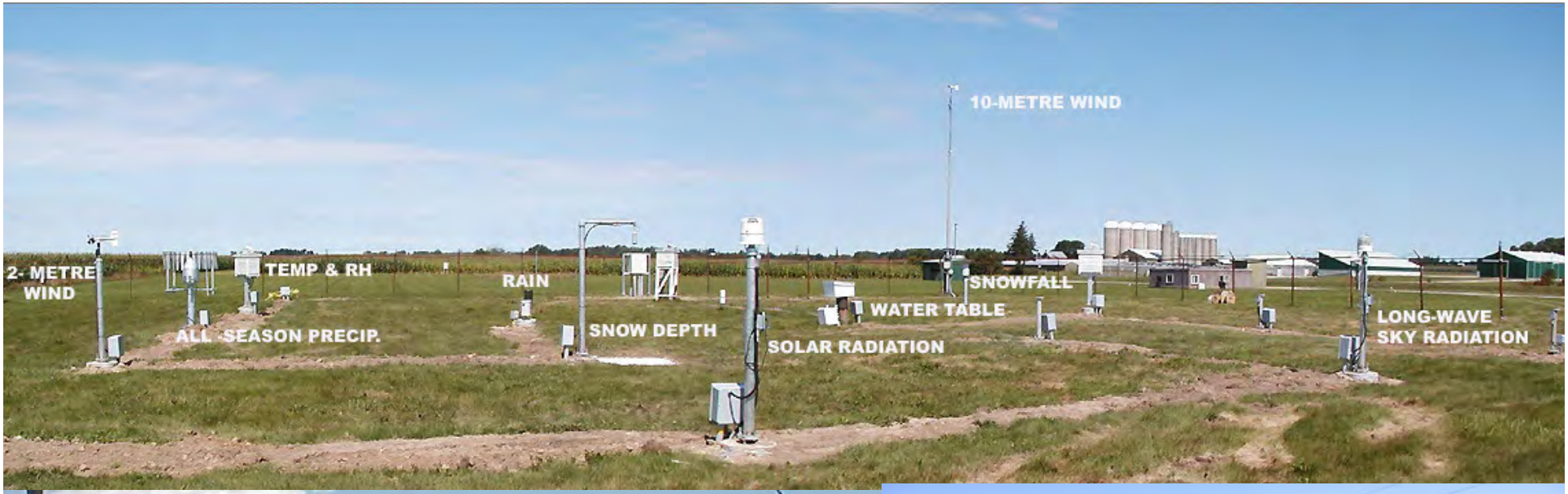
- Guelph Sites
- Environment Canada Sites
- Cities/Towns
- Rivers
- Lakes
- Unclassified
- Clay
- Loam
- Sand Loam
- Clay Loam
- Sand

KEY MAP OF SOUTHERN SASKATCHEWAN

Data Sources:

University of Saskatchewan (2002)
Environment Canada (2007)


SOIL TEXTURES IN ONTARIO OBSERVATORY
N
1:500,000
0 2.5 5 10 15 20 25
Kilometers
Legend
Study Sites
Cities/Towns
Rivers
Soil Textures
Organic
Unclassified
Loam
Sand Loam
Clay Loam
Silt Loam
KEY MAP OF SOUTHERN ONTARIO
U.S.A
U.S.A
Legend
Study Area
Upper Tier Municipality
Data Sources:
Agricorp (2006)
Ontario Ministry of Natural Resources (2005)
Ontario Ministry of Agriculture, Food and Rural Affairs (2004)
Durham
Walkerton
Mildmay
Teeswater
Clifford
Mount Forest
Harriston
Arthur
Drayton
Listowel
Elora
Milverton
Mitchell

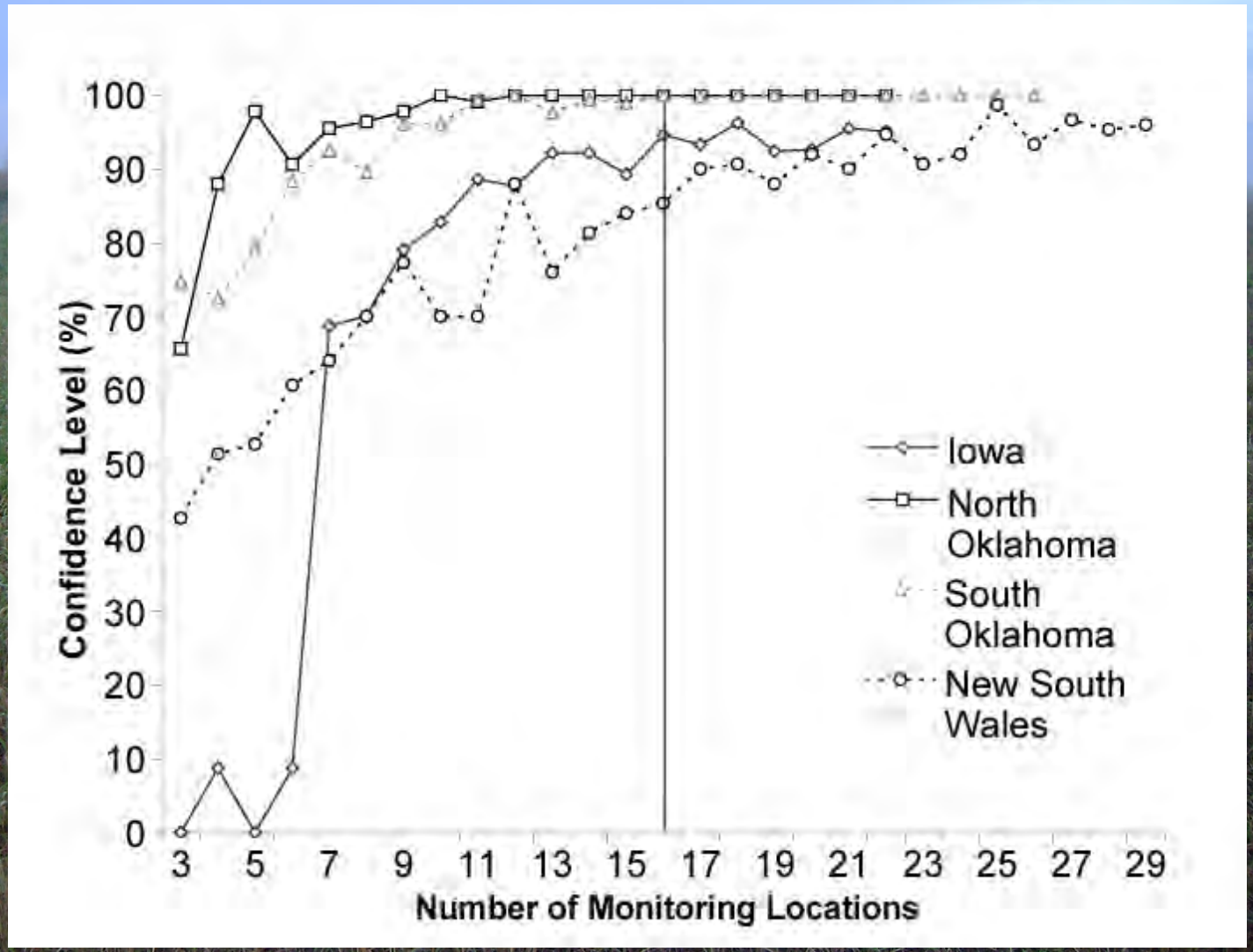

10-METRE WIND
2- METRE WIND
TEMP & RH
RAIN
SNOWFALL
WATER TABLE
LONG-WAVE SKY RADIATION
ALL SEASON PRECIP.
SNOW DEPTH
SOLAR RADIATION

Design Challenges

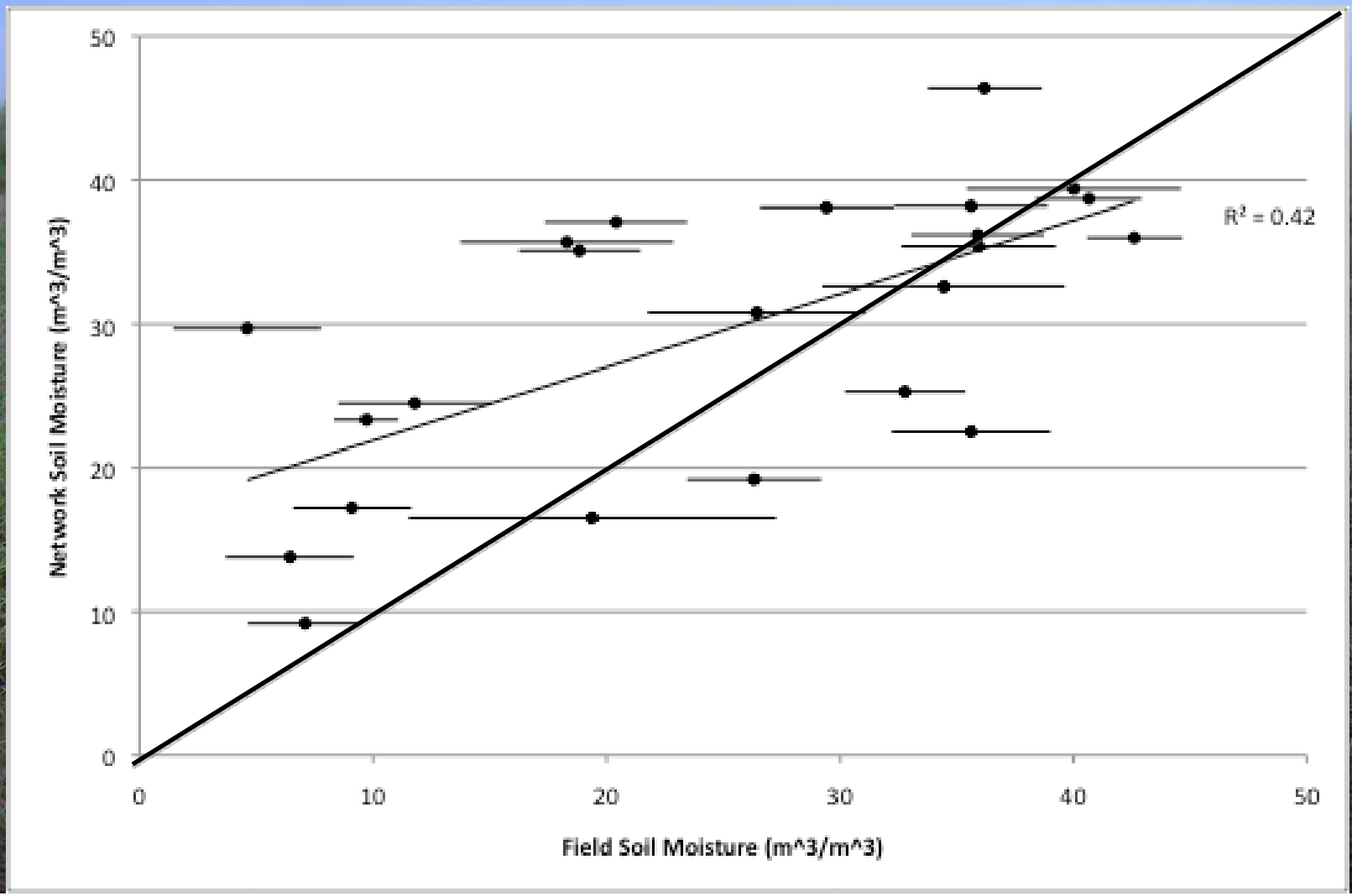
- Purpose of network?
- Issues for design of satellite validation networks

Development of Paired Soil Moisture Sampling Networks for Satellite and Model Validation

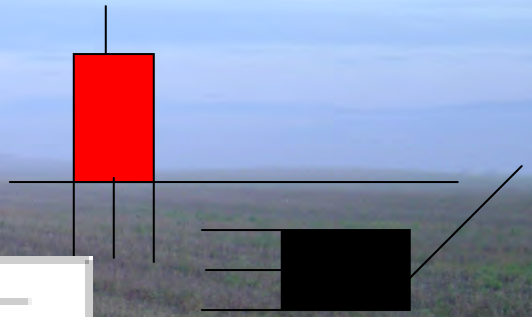
How Many Sensors?

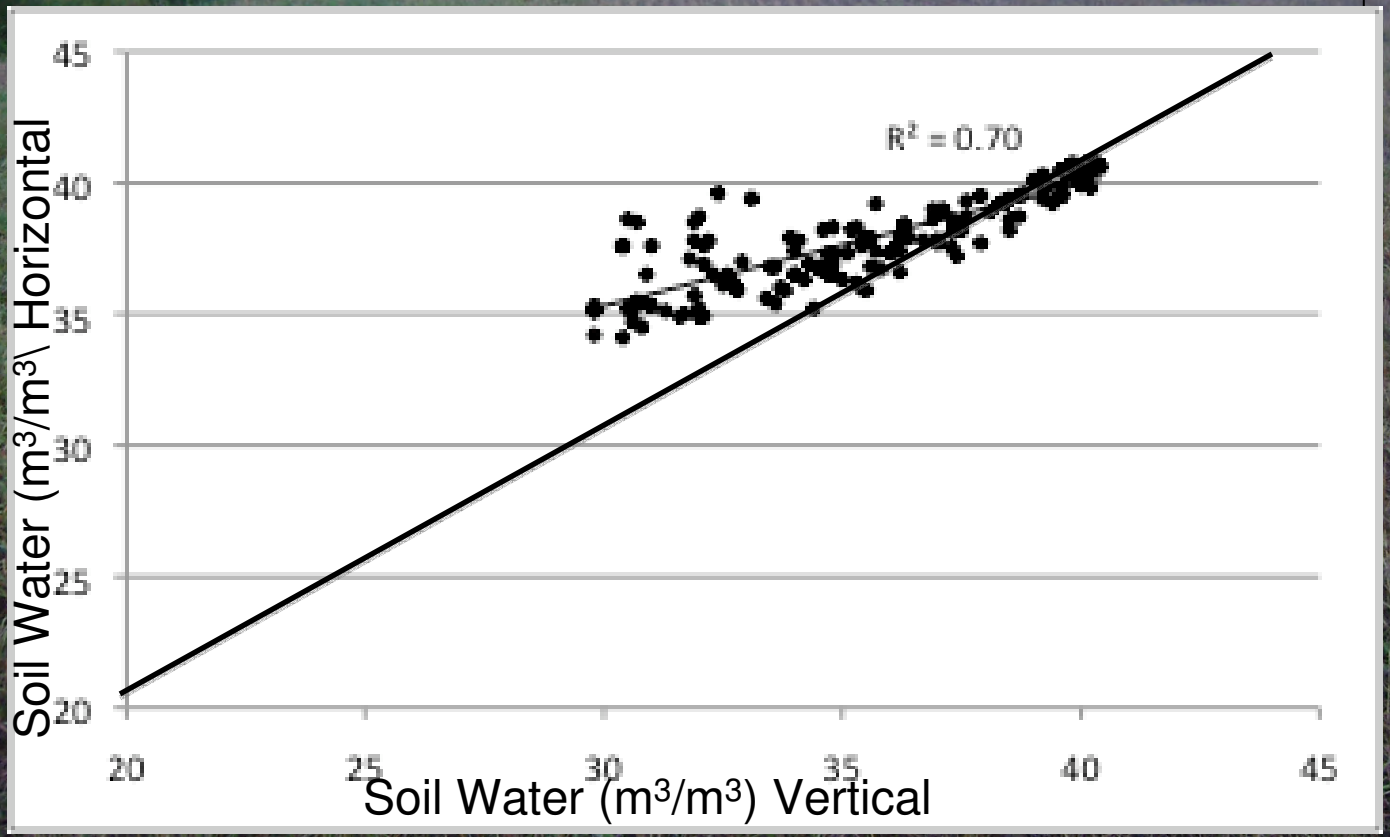


How representative are the network measurements compared to field conditions?

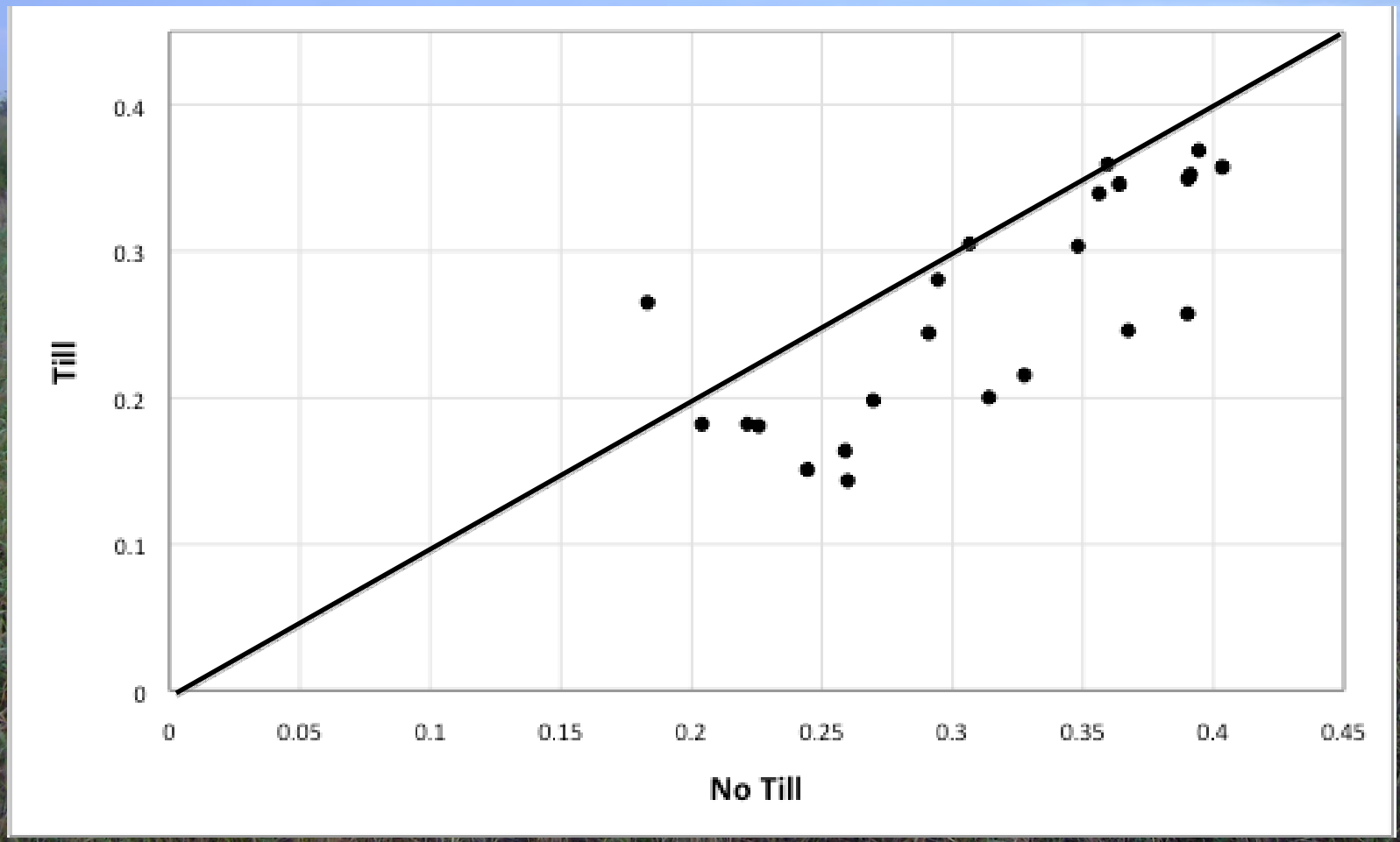


Impact of Sensor Orientation?



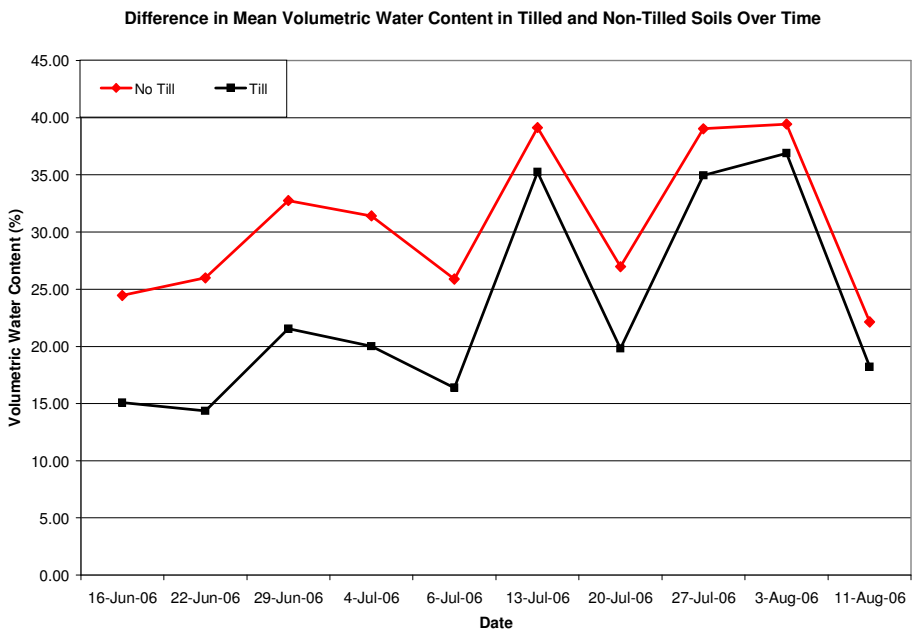


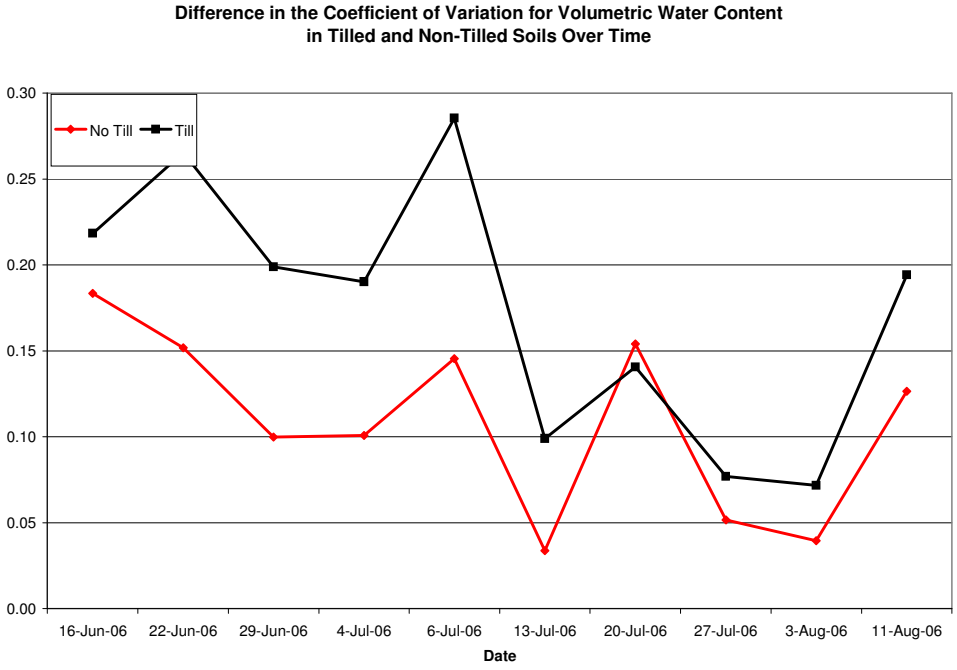
Impact of Land-use Practices: Tillage



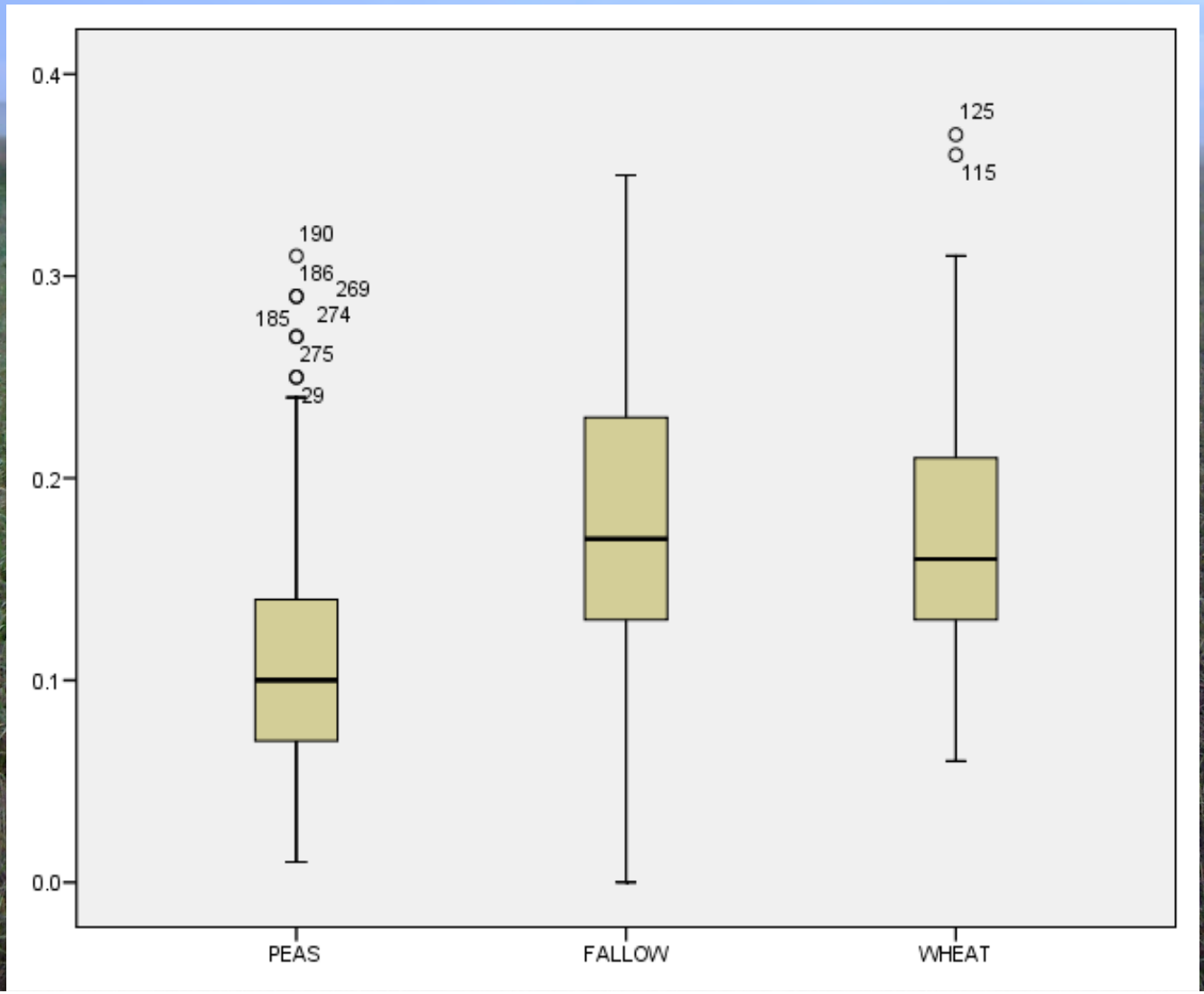
Impacts of Land-use Practices:

Tillage





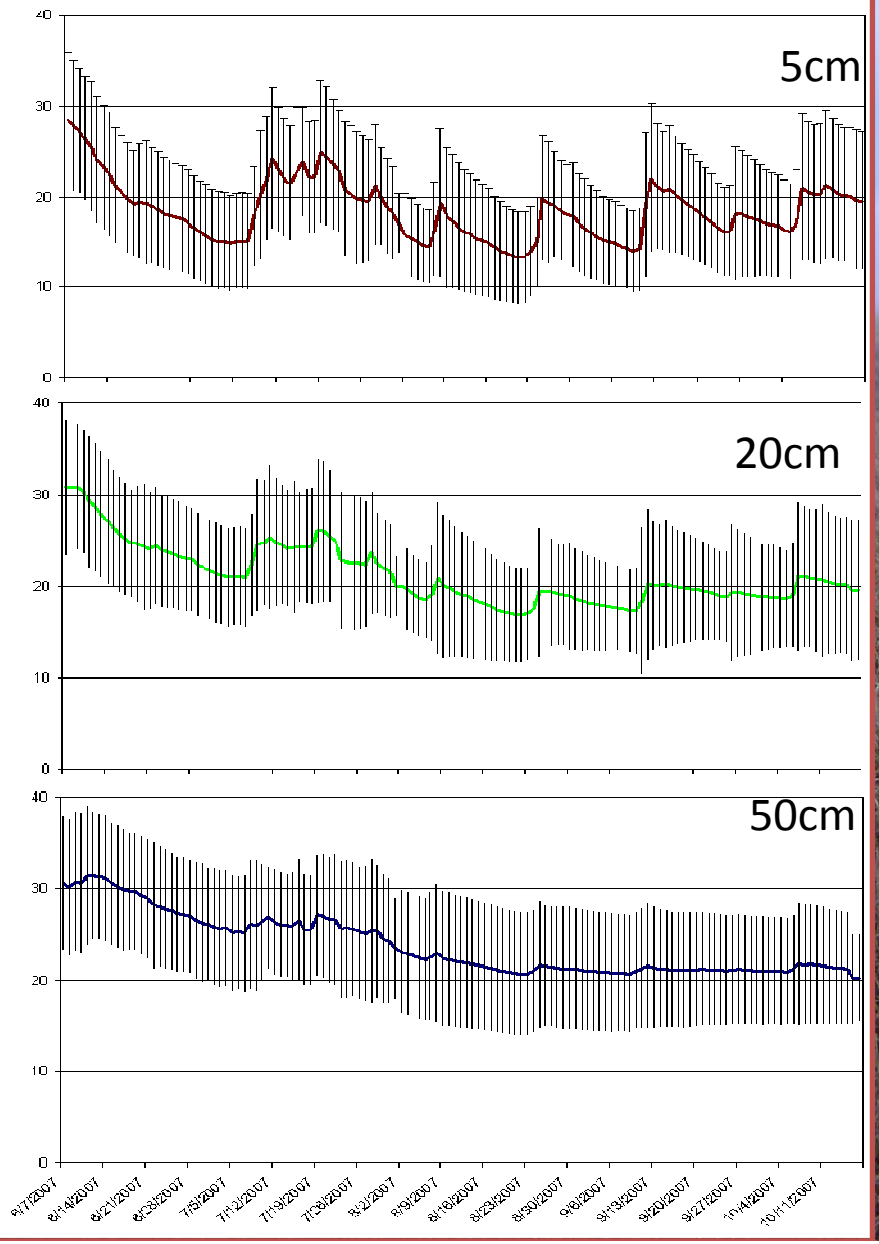
Impact of crop cover on mean soil moisture and variability

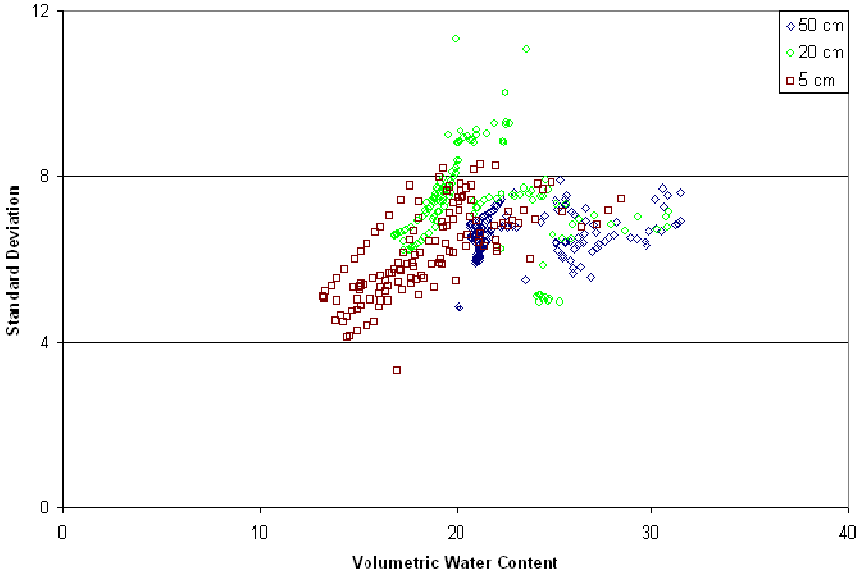


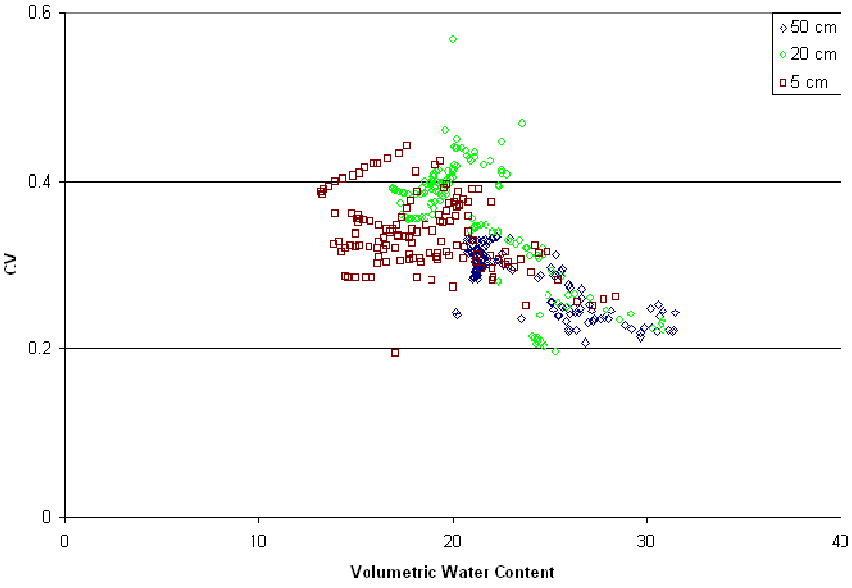
Applications of Soil Moisture Monitoring Networks

- Controls on soil moisture variability
- Evaluation of remote sensing soil moisture products
- Evaluation of data assimilation products and methods

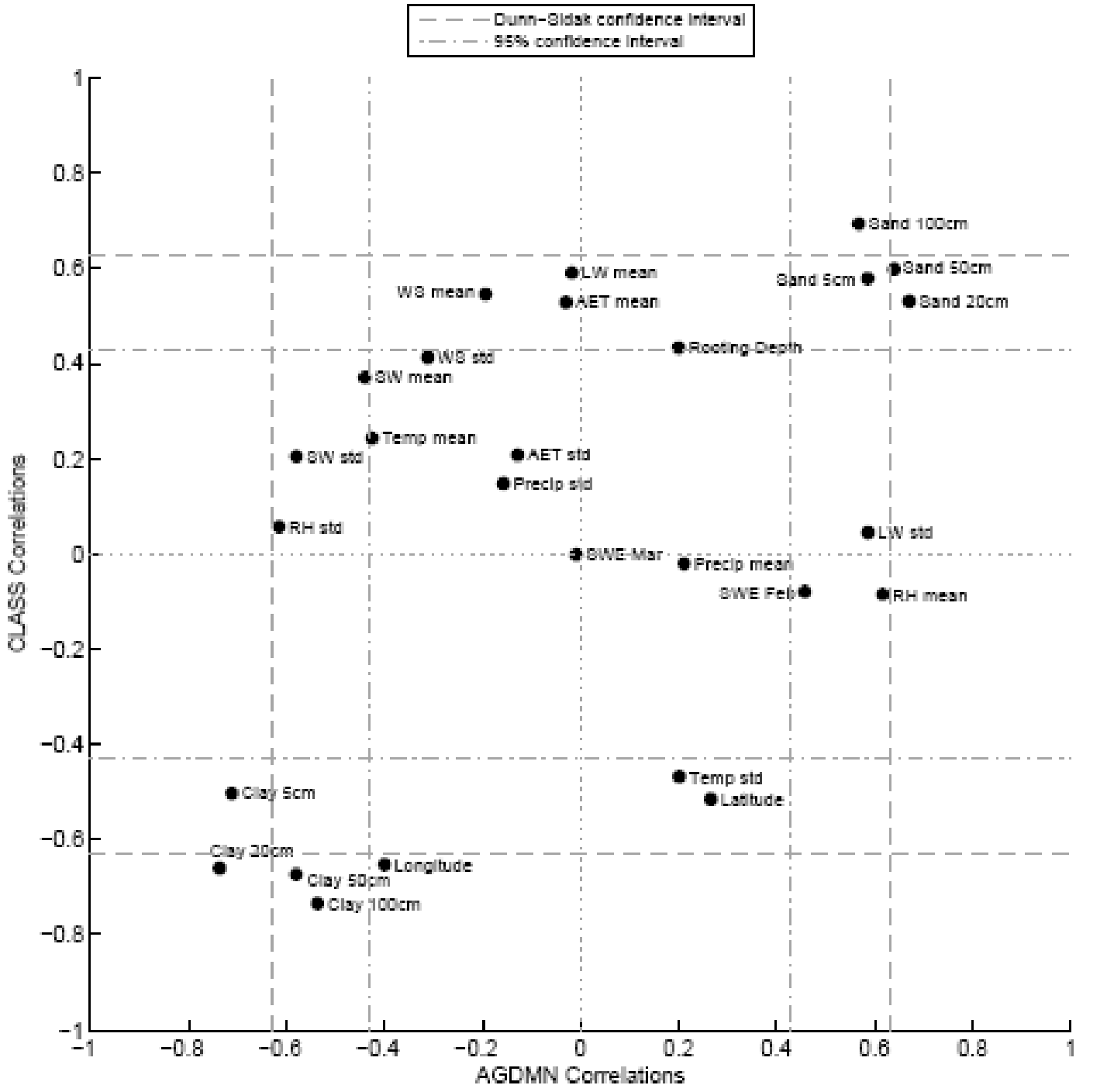
Soil Moisture and Variability Time Series

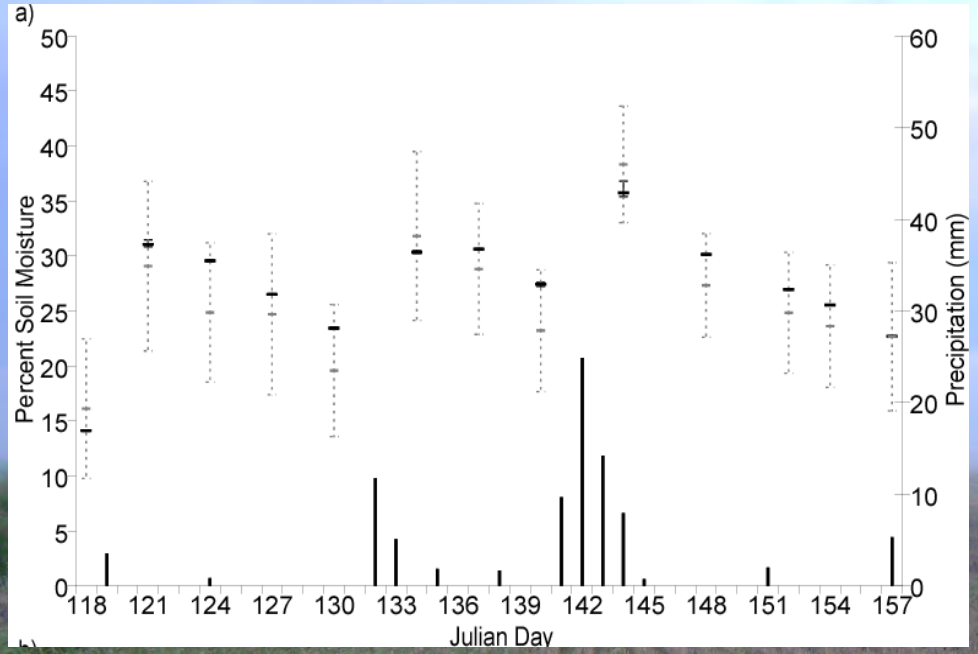


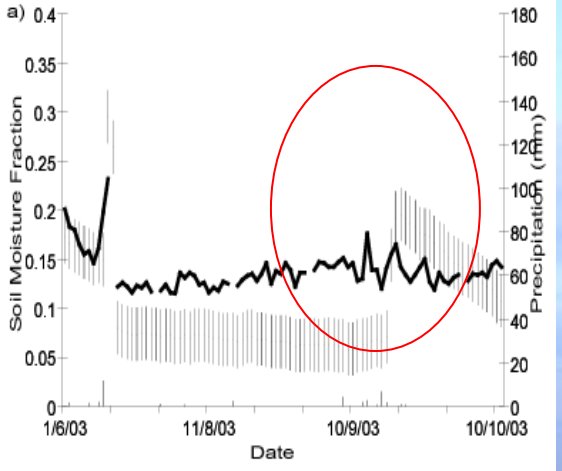


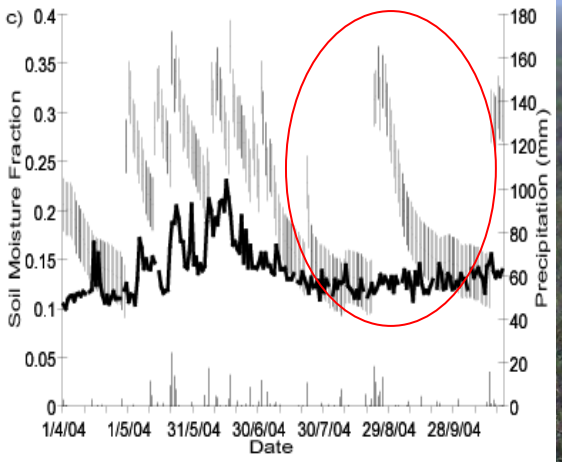


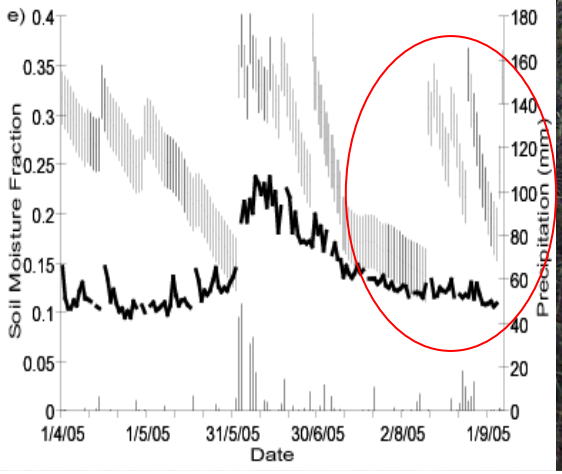
Controls on soil moisture variability in Alberta. Correlation of physical processes to the first Principal Component (47% of variability) for the Alberta Drought Monitoring Network and CLASS

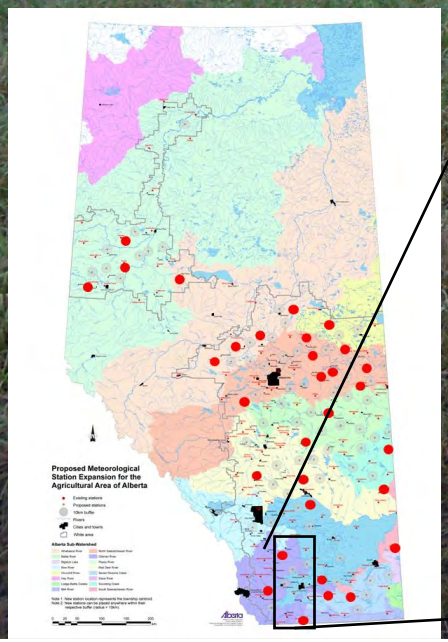


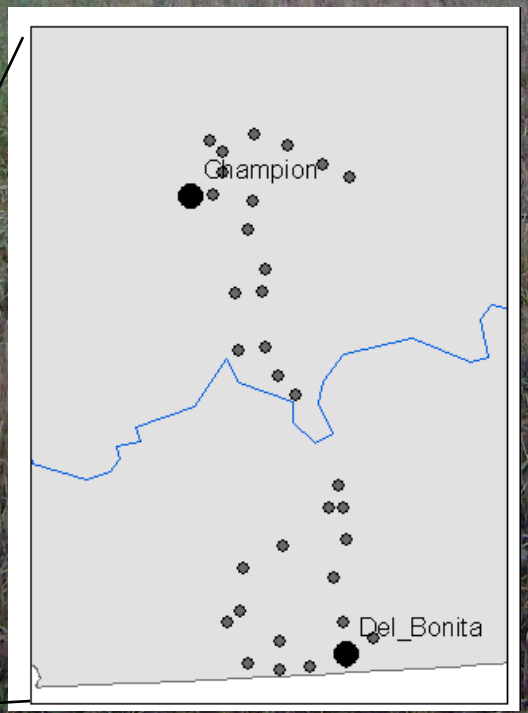

a)
Percent Soil Moisture
Precipitation (mm)
Julian Day


a)
Soil Moisture Fraction
Precipitation (mm)
Date

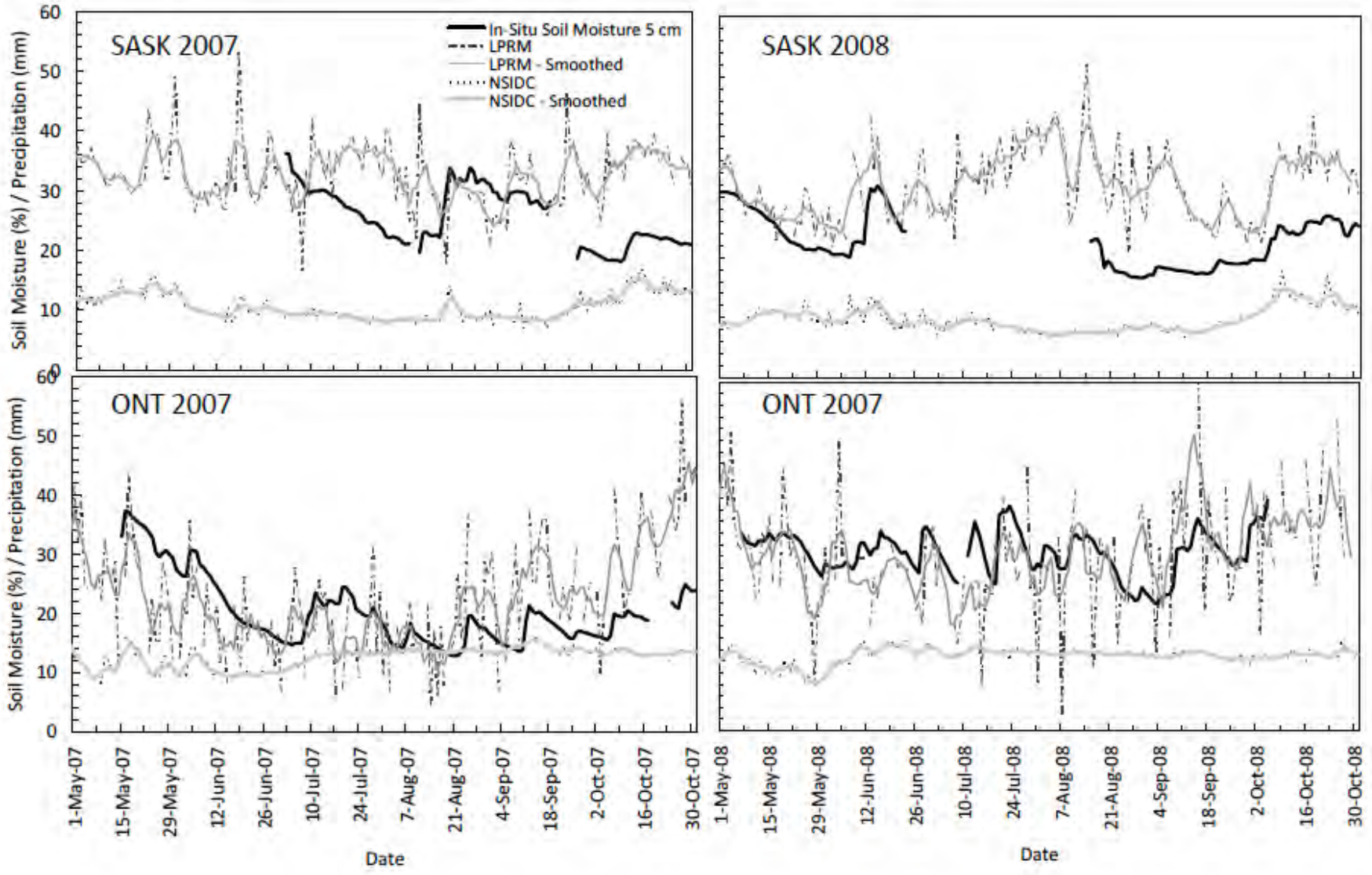

c)
Soil Moisture Fraction
Precipitation (mm)
Date


e)
Soil Moisture Fraction
Precipitation (mm)
Date


Proposed Meteorological Station Expansion for the Agricultural Area of Alberta


Champion
Del_Bonita

Validation of Soil Moisture Estimate from Microwave Brightness Temperatures



Correlations of satellite derived soil moisture to network observations

	LPRM C/X-Band		NSIDC X-Band		SSM/I	
ONT	R	Anomaly RMSE (%)	R	Anomaly RMSE (%)	R	Anomaly RMSE (%)
All	**0.54**	0.91	-0.06	1.25	**0.44**	1.01
MJ	***0.80***	*0.99*	***0.57***	*1.53*	***0.54***	*1.20*
JA	***0.79***	*0.77*	*0.31*	*0.93*	***0.63***	*0.82*
SO	***0.70***	*1.00*	***-0.57***	*1.25*	*0.25*	*1.05*
SASK						
All	0.08	1.34	-0.04	1.38	0.02	1.54
MJ	***0.71***	*1.65*	*-0.28*	*1.28*	*0.29*	*1.98*
JA	*-0.18*	*1.57*	***0.82***	*1.16*	*0.11*	*1.67*
SO	*0.23*	*1.27*	*0.11*	*1.81*	*0.02*	*1.62*

Table 7. Relationship between in-situ and satellite derived soil moisture for 2007 and 2008 growing seasons. In-situ soil moisture is the weekly average of all available soil moisture stations within each study area. The LPRM soil moisture is derived from C-band with X-band substituted where RFI is detected, the NSIDC is derived from X-band only. Anomalies represent standard normal deviates. Values in bold are significant at $p<0.05$.

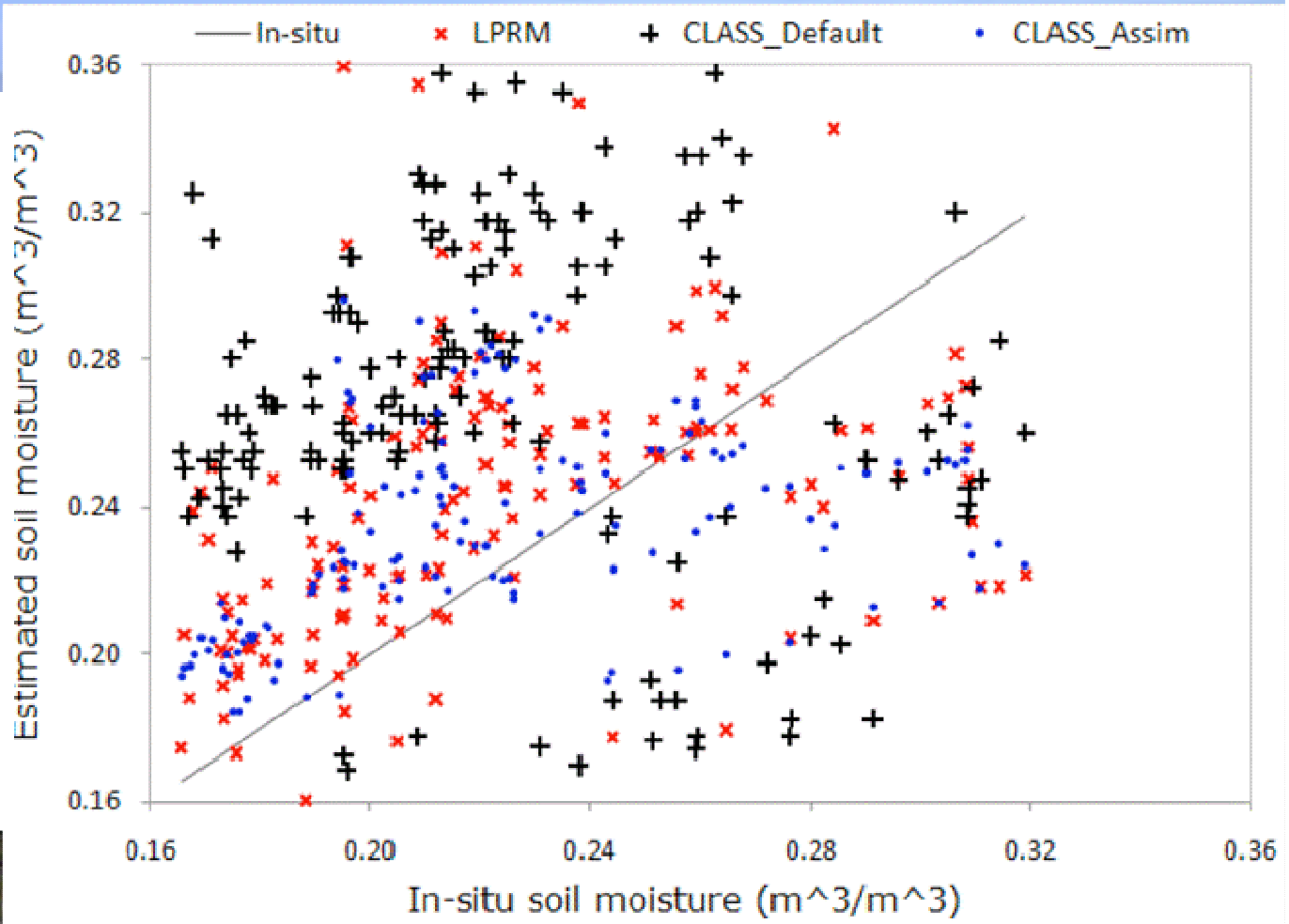
Improving soil moisture retrievals of the LPRM through parameter adjustment

	Measure	Jul 27 2007 - Oct 31 2007	May 1 2008 - Jun 23 2008	Aug 21 2008 - Oct 28 2008	Overall
Asc6.9	Bias	0.0535	-0.0174	0.0275	0.0172
	RMSE	0.0621	0.0484	0.0394	0.0486
	d	0.9832	0.9904	0.9920	0.9893
	R	0.2024	0.2307	0.7328	0.3261
Desc6.9	Bias	0.0741	-0.0016	0.0406	0.0330
	RMSE	0.0833	0.0374	0.0597	0.0595
	d	0.9723	0.9947	0.9827	0.9850
	R	0.2500	0.6669	0.4769	0.3976
LPRM-Asc	Bias	0.1025	0.0080	0.0839	0.0608
	RMSE	0.1110	0.0723	0.0890	0.0892
	d	0.9559	0.9808	0.9680	0.9699
	R	-0.0318	0.1741	0.7075	0.1301
LPRM-Desc	Bias	0.1181	0.0159	0.0808	0.0659
	RMSE	0.1352	0.0854	0.1335	0.1189
	d	0.9389	0.9744	0.9287	0.9484
	R	0.1965	0.3318	-0.0505	0.0238

Note: d = degree of agreement, R = pairwise correlation coefficient.

Use of Network data for evaluation of data assimilation approaches

	Measure	Overall
LPRM(Desc0.9)	Bias	0.0173
	RMSE	0.0483
	d	0.9894
	R	0.3279
CLASS Default	Bias	0.0347
	RMSE	0.0531
	d	0.9880
	R	0.1714
Assimilated	Bias	0.0105
	RMSE	0.0373
	d	0.9935
	R	0.5618

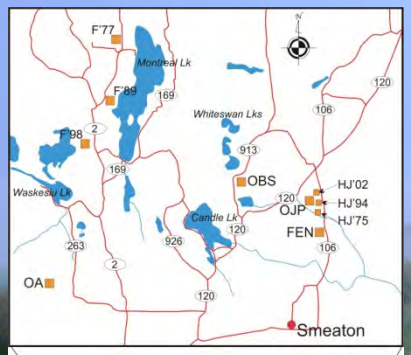


RADARSAT-2 Validation Field Campaign near Saskatoon, Saskatchewan, July, 2008

Sampling Data Set:

- vegetation cover, water content, height and density.
- Surface roughness
- soil properties
- 6000+ observations of surface soil moisture and temperature were obtained over a 20x20km region.

Canadian SMOS Validation Campaign 2010



- Time: May-June 2010
- Locations: Boreal Forest and Agricultural Regions of Saskatchewan
- Support: NSERC (~500K), Environment Canada in kind contributions
- Ground Support: Nested monitoring networks and BERMS; vegetation and soil moisture measurement teams
- Aircraft Support: Environment Canada (Anne Walker)

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•Kathyrn Powell
•Luke Powell
•Matt Reid
•Jess Rogers
•Brenda Toth
•Ingrid Volet
•Jeff Walker
•Ralph Wright

Funding and Agencies

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•Environment Canada
•Agriculture and Agriculture and Agri-Food Canada
•National Science and Engineering Research Council
•Ontario Ministry of Agriculture Food and Rural Affairs
•Canadian Foundation for Innovation
•Ontario Research Trust
•Canadian Foundation for Climate and Atmospheric Science